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APPLICATION FOR UNITED STATES PATENT

FOR

**SYSTEM, DEVICE, AND METHOD FOR PRODUCING OPTICAL DATA  
STREAMS IN AN OPTICAL COMMUNICATION NETWORK**

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## SYSTEM, DEVICE, AND METHOD FOR PRODUCING OPTICAL DATA STREAMS IN AN OPTICAL COMMUNICATION NETWORK

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### FIELD OF THE INVENTION

The present invention relates generally to optical networking, and more particularly to producing optical data streams in an optical communication network.

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### BACKGROUND OF THE INVENTION

An optical data stream is typically produced by modulating an optical carrier. A laser generates an optical carrier at a predetermined wavelength, and an external modulator coupled to the laser output modulates the optical carrier according to a data signal applied to the external modulator. The resulting optical data stream can be carried over the optical communication network.

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There are generally two types of lasers, namely fixed wavelength lasers and tunable lasers. A fixed wavelength laser is capable of generating an optical carrier at a single wavelength. A tunable laser is capable of generating an optical carrier at any of a number of wavelengths. Tunable lasers are generally more flexible than fixed wavelength lasers, but cost substantially more than fixed wavelength lasers.

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In an optical communication network that supports  $M$  wavelengths, it is sometimes necessary or desirable to produce  $N$  optical data streams at  $N$  specific wavelengths (where  $N$  is less than  $M$ ).

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One way to accomplish this is to use  $N$  tunable lasers coupled to  $N$  external modulators. Each of the  $N$  tunable lasers is tuned to one of the  $N$  specific wavelengths, and each of  $N$  data sources is fed into one of the  $N$  external modulators. This produces  $N$  optical data streams at the  $N$  specific

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wavelengths. An advantage of this solution is that it uses a relatively small amount of equipment. A disadvantage of this solution, however, is that it is expensive due to the use of tunable lasers.

5 Another way to accomplish this is to use M fixed wavelength lasers coupled to M external modulators. The N data signals are fed into those N external modulators that are associated with the N fixed wavelength lasers having the N specific wavelengths, for example, using a cross-connect switch. This produces N optical data streams at the N specific wavelengths. An  
10 advantage of this solution is that it is relatively inexpensive compared to the tunable laser solution. A disadvantage of this solution, however, is that it uses a relatively large amount of equipment.

15 **SUMMARY OF THE INVENTION**

In accordance with one aspect of the invention, M fixed wavelength lasers and N external modulators ( $N < M$ ) are used to produce N optical data streams. The M fixed wavelength lasers are coupled to the N external  
20 modulators through a photonic cross-connect switch that is capable of routing the outputs of any N of the M fixed wavelength lasers to the N external modulators. The photonic cross-connect switch is configured to route N optical carriers at N specific wavelengths to the N external modulators. N data signals are fed to the N external modulators for producing N optical data  
25 streams at the N specific wavelengths. The photonic cross-connect switch maintains the polarity of the N optical carriers that are routed to the N external modulators.

In accordance with another aspect of the invention, a photonic cross-  
30 connect switch includes polarization maintaining means for maintaining the polarity of optical carriers routed from any N of M optical inputs to N optical outputs. In a typical embodiment, polarization maintaining fibers are used

for coupling M optical inputs to a photonic cross-connect fabric and for coupling N optical outputs to the photonic cross-connect fabric.

5                    **BRIEF DESCRIPTION OF THE DRAWINGS**

The foregoing and other objects and advantages of the invention will be appreciated more fully from the following further description thereof with reference to the accompanying drawings wherein:

10            FIG. 1 is a system diagram showing an exemplary optical communication system in which N tunable lasers and N external modulators are used to produce N optical data streams at N specific wavelengths, as is known in the art;

15            FIG. 2 is a system diagram showing an exemplary optical communication system in which M fixed wavelength lasers and M external modulators are used to produce N optical data streams at N specific wavelengths, as is known in the art;

20            FIG. 3 is a system diagram showing an exemplary optical communication system in which M fixed wavelength lasers and N external modulators are used in conjunction with a MEMS (Micro Electro Mechanical System) to produce N optical data streams at N specific wavelengths, in accordance with an embodiment of the present invention;

FIG. 4 is a block diagram showing the relevant logic blocks of the MEMS in accordance with an embodiment of the present invention; and

25            FIG. 5 is a system diagram showing an exemplary communication system for producing four optical data streams at any four of sixteen wavelengths, in accordance with an embodiment of the present invention.

30            **DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT**

As discussed above, in an optical communication network that supports M wavelengths, it is sometimes necessary or desirable to produce N

optical data streams at  $N$  specific wavelengths (where  $N$  is less than  $M$ ). An embodiment of the present invention uses  $M$  fixed wavelength lasers and  $N$  external modulators to produce the  $N$  optical data streams. The  $M$  fixed wavelength lasers are coupled to the  $N$  external modulators through a

5 photonic cross-connect switch. The photonic cross-connect switch includes at least  $M$  optical inputs that are coupled to the outputs of the  $M$  fixed wavelength lasers, and also includes at least  $N$  optical outputs that are coupled to the inputs of the  $N$  external modulators. Within the photonic cross-connect switch, the  $M$  optical inputs are coupled to the  $N$  optical

10 outputs through a photonic cross-connect fabric that is capable of routing any  $N$  of the  $M$  optical inputs to the  $N$  optical outputs. The photonic cross-connect fabric may be based upon Micro Electro Mechanical System (MEMS) technology, Micro Opto Electro Mechanical System (MOEMS) technology, bubble (champagne) technology, lithium niobate technology, liquid crystal

15 technology, or other photonic switching technology. Optical connections within the photonic cross-connect switch (e.g., from the  $M$  optical inputs to the photonic cross-connect fabric and from the photonic cross-connect fabric to the  $N$  optical outputs) preferably use polarization maintaining (PM) fiber in order to maintain the polarity of the optical carriers from input to output. In

20 order to produce  $N$  optical data streams at  $N$  specific wavelengths, the photonic cross-connect switch is configured to route those  $N$  optical inputs having the  $N$  specific wavelengths to the  $N$  optical outputs. The  $N$  data signals are fed into the  $N$  external modulators. This produces  $N$  optical data streams at the  $N$  specific wavelengths using  $M$  fixed wavelength lasers and  $N$

25 external modulators.

FIG. 1 shows an exemplary optical communication system 100 in which  $N$  tunable lasers and  $N$  external modulators are used to produce  $N$  optical data streams at  $N$  specific wavelengths, as is known in the art. The output of

30 each of the  $N$  tunable lasers  $102_1-102_N$  is coupled to the input of one of the  $N$  external modulators  $104_1-104_N$ . Each of the  $N$  tunable lasers  $102_1-102_N$  is tuned to one of the  $N$  specific wavelengths, and each of  $N$  data sources  $106_1-106_N$  is

fed into one of the  $N$  external modulators  $104_1-104_N$ . This produces  $N$  optical data streams  $108_1-108_N$  at the  $N$  specific wavelengths.

FIG. 2 shows an exemplary optical communication system 200 in which  
5  $M$  fixed wavelength lasers and  $M$  external modulators are used to produce  $N$  optical data streams at  $N$  specific wavelengths, as is known in the art. The output of each of the  $M$  fixed wavelength lasers  $202_1-202_M$  is coupled to the input of one of the  $M$  external modulators  $204_1-204_M$ . A digital cross-connect switch 210 is coupled between the  $N$  data signals  $206_1-206_N$  and the  $M$  external  
10 modulators  $204_1-204_M$ . The digital cross-connect switch 210 is capable of routing the  $N$  data signals  $206_1-206_N$  to any  $N$  of the  $M$  external modulators  $204_1-204_M$ . The digital cross-connect switch 210 is configured to route the  $N$  data signals  $206_1-206_N$  to those  $N$  of the  $M$  external modulators  $204_1-204_M$  that are associated with those  $N$  of the  $M$  fixed wavelength lasers  $202_1-202_M$  having  
15 the  $N$  specific wavelengths. This produces  $N$  optical data streams  $208_1-208_N$  at the  $N$  specific wavelengths.

FIG. 3 shows an exemplary optical communication system 300 in which  
20  $M$  fixed wavelength lasers and  $N$  external modulators are used to produce  $N$  optical data streams at  $N$  specific wavelengths. The outputs of the  $M$  fixed wavelength lasers  $302_1-302_M$  are coupled to the optical inputs of the photonic cross-connect switch 310, and the outputs of the photonic cross-connect switch 310 are coupled to the inputs of the  $N$  external modulators  $304_1-304_N$ . The photonic cross-connect switch 310 is configured to route the outputs of  
25 those  $N$  of the  $M$  fixed wavelength lasers  $302_1-302_M$  having the  $N$  specific wavelengths to the inputs of the  $N$  external modulators  $304_1-304_N$ . Each of  $N$  data sources  $306_1-306_N$  is fed into one of the  $N$  external modulators  $304_1-304_N$ . This produces  $N$  optical data streams  $308_1-308_N$  at the  $N$  specific wavelengths.

30 FIG. 4 is a block diagram showing the relevant components of the photonic cross-connect switch 310. Among other things, the photonic cross-connect switch 310 includes at least  $M$  optical inputs  $402_1-402_M$  that are

coupled to a photonic cross-connect fabric 406 via PM fibers 404<sub>1</sub>-404<sub>M</sub>. The photonic cross-connect switch 310 also includes at least N optical outputs 410<sub>1</sub>-410<sub>N</sub> that are coupled to the photonic cross-connect fabric 406 via PM fibers 408<sub>1</sub>-408<sub>N</sub>. The photonic cross-connect fabric 406 is capable of routing any N of the M optical inputs 402<sub>1</sub>-402<sub>M</sub> to the N optical outputs 410<sub>1</sub>-410<sub>N</sub>. The photonic cross-connect switch 310 maintains the polarity of the optical carriers that are switched from the N of the M optical inputs 402<sub>1</sub>-402<sub>M</sub> to the N optical outputs 410<sub>1</sub>-410<sub>N</sub>.

FIG. 5 shows an exemplary optical communication system 500 for producing four optical data streams at any four of sixteen wavelengths. The outputs of sixteen fixed wavelength lasers 502<sub>1</sub>-502<sub>16</sub>, which produce fixed wavelengths  $\lambda_1$ - $\lambda_{16}$ , respectively, are coupled to the inputs of the photonic cross-connect switch 510. The outputs of the photonic cross-connect switch 510 are coupled to the inputs of four external modulators 504<sub>1</sub>-504<sub>4</sub>. The photonic cross-connect switch 510 is capable of routing the outputs of any four of the sixteen fixed wavelength lasers 502<sub>1</sub>-502<sub>16</sub> to the four external modulators 504<sub>1</sub>-504<sub>4</sub>. In this example, the photonic cross-connect switch 510 is configured to route the output of fixed wavelength laser 502<sub>2</sub> ( $\lambda_2$ ) to external modulator 504<sub>1</sub>, route the output of fixed wavelength laser 502<sub>6</sub> ( $\lambda_6$ ) to external modulator 504<sub>2</sub>, route the output of fixed wavelength laser 502<sub>10</sub> ( $\lambda_{10}$ ) to external modulator 504<sub>3</sub>, and route the output of fixed wavelength laser 502<sub>14</sub> ( $\lambda_{14}$ ) to external modulator 504<sub>4</sub>. Data signal 506<sub>1</sub> is fed to external modulator 504<sub>1</sub> to produce optical data stream 508<sub>1</sub> at wavelength  $\lambda_2$ . Data signal 506<sub>2</sub> is fed to external modulator 504<sub>2</sub> to produce optical data stream 508<sub>2</sub> at wavelength  $\lambda_6$ . Data signal 506<sub>3</sub> is fed to external modulator 504<sub>3</sub> to produce optical data stream 508<sub>3</sub> at wavelength  $\lambda_{10}$ . Data signal 506<sub>4</sub> is fed to external modulator 504<sub>4</sub> to produce optical data stream 508<sub>4</sub> at wavelength  $\lambda_{14}$ .

It should be noted the photonic cross-connect switch (310, 510) preferably maintains the polarity of each optical carrier from input to output.

In exemplary embodiments of the invention, PM fibers are used to maintain the polarity of optical carriers from input to output within the photonic cross-connect switch. However, alternative techniques for maintaining the polarity of optical carriers from input to output within the photonic cross-connect switch may also be used, and are intended to fall within the scope of the present invention.

The present invention may be embodied in other specific forms without departing from the true scope of the invention. The described embodiments are to be considered in all respects only as illustrative and not restrictive.

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